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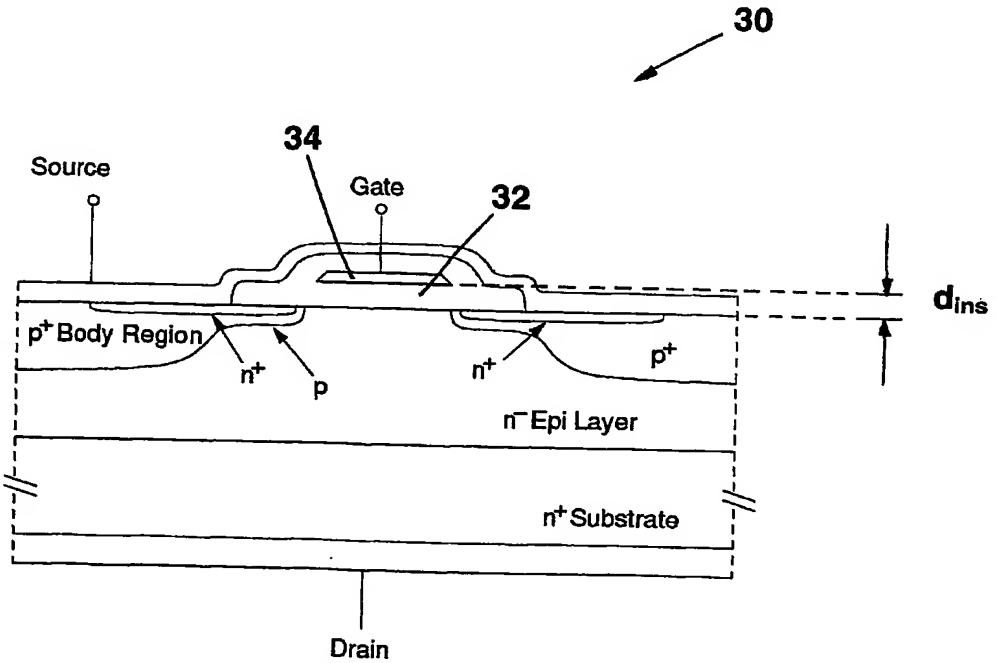
(54) Title: FAST SWITCHING POWER INSULATED GATE SEMICONDUCTOR DEVICE



(57) Abstract: An insulated gate semiconductor device (30) includes a gate (34), a source terminal (36), a drain terminal (38) and a variable input capacitance at the gate. A ratio between the input capacitance (C_{fiss}) when the device is on and the input capacitance C_{iiss} when the device is off is less than two and preferably substantially equal to one. This is achieved in one embodiment of the invention by an insulation layer (32) at the gate having an effective thickness d_{ins} than a minimum thickness.

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FAST SWITCHING POWER INSULATED GATE SEMICONDUCTOR DEVICE

TECHNICAL FIELD

THIS invention relates to insulated gate semiconductor devices such as metal oxide silicon field effect transistors (MOSFET's), more particularly to such devices for use in power switching applications and to a method of driving such devices.

BACKGROUND ART

In known MOSFET structures, it is presently preferred to minimize the gate voltage V_{GS} required for switching of the device and which then implies a relatively large input gate capacitance.

Capacitance inherent in the gate structures of insulated gate devices limits the switching speeds of these devices. It is also well known that the Miller effect has an influence on the input capacitance at the gate of devices of the aforementioned kind in that the input capacitance of a typical commercially available MOSFET varies during switching of the device. The input capacitance has a first value C_{iiss} when the device is off and a second value C_{fiss} when the device is on. The ratio of the second and first values for a known and commercially available IRF 740

power MOSFET is in the order of 2.5. It has been found that such a ratio impairs the switching speed of these devices.

The total switching time T_s of the IRF 740 MOSFET to switch on is made up by the sum of a turn-on delay time T_{don} of about 14ns and a drain source voltage fall time T_f of about 24ns and is equal to about 38ns. The corresponding time to switch off is about 77ns. These times are too long for some applications.

OBJECT OF THE INVENTION

Accordingly, it is an object of the present invention to provide an insulated gate device and method and circuit of driving such a device with which the applicant believes the aforementioned disadvantages may at least be alleviated.

SUMMARY OF THE INVENTION

According to the invention an insulated gate device comprises a gate connected to a gate terminal and having a variable input capacitance at the gate terminal as the device is switched between an off state and an on state, a ratio between a final value of the capacitance when the device is on and an initial value of the capacitance when the device is off is smaller than 2.0.

The aforementioned ratio is preferably less than 1.5, more preferably less than 1.4, even more preferably less than 1.3, still more preferably less than 1.2 and most preferably substantially equal to 1.

The device may comprise a semiconductor device, preferably a field effect transistor (FET) more preferably a power metal oxide silicon field effect transistor (MOSFET) such as a V-MOS, D-MOS and U-MOS.

The MOSFET may have a vertical structure in that the gate and a source of the device are provided on one face of a chip body of the device and a drain of the MOSFET is provided on an opposite face of the body.

The device may comprise a capacitor connected between the gate terminal and the gate of the device.

The capacitor may be integrated on the chip body and in one embodiment may be superimposed on the gate of the device.

Alternatively, the capacitor is a discrete component connected in

series between the gate and the gate terminal and packaged in the same package.

The gate may be connected directly to a fourth terminal of the device.

In this specification the invariant device parameter (β) is used to denote the effective dielectricum thickness of a conduction channel of the device in the off state, which is defined as the product of an effective gate capacitance area (A) and the difference between an inverse of a first value of a gate capacitance of the insulated gate device, that is when the device is off and an inverse of a second value of the gate capacitance, that is when the device is on. That is:

$$\beta \equiv A(1/C_{iiss} - 1/C_{fiss}) = \propto_{max.}$$

According to one aspect of the invention there is provided an insulated gate device comprising a gate and an insulation layer at the gate, the layer having an effective thickness (d) of at least a quotient of the device parameter as defined and a ratio of maximum charge accommodatable on the gate and a minimum charge required on the gate for complete switching, minus one (1). That is:

$$d \geq d_{min} \approx \beta / [(Q_{G(max)} / Q_{G(min)}) - 1]$$

where $Q_{G(max)}$ is the maximum allowable steady state charge for safe operation and $Q_{G(min)}$ is the minimum charge required for complete switching.

According to another aspect of the invention there is provided an insulated gate device comprising a gate, the device having a capacitance at the gate which is a function of the effective thickness of an insulation layer at the gate, the effective thickness of the layer being selected to ensure that a first ratio between a final value of the capacitance when the device is on and an initial value of the capacitance when the device is off is smaller or equal to a second ratio of a maximum charge receivable on the gate and a charge required to reach a threshold voltage of the gate of the device.

According to yet another aspect of the invention there is provided an insulated gate device comprising a gate, the device having a capacitance at the gate which is a function of the effective thickness of an insulation layer at the gate, the effective thickness of the layer being selected to ensure that a first ratio between a final value of the capacitance when the device is on and an initial value of the capacitance when the device is off is smaller or equal to a second

ratio of a maximum voltage applyable to the gate and a threshold voltage required on the gate to switch the device on.

According to yet another aspect of the invention there is provided a method of driving an insulated gate semiconductor device, the device comprising an insulation layer at a gate thereof providing a capacitance which varies between an initial value when the device is off and a final value when the device is on, the method comprising the step of depositing at least a Miller charge on the gate while the capacitance has said initial value.

The method preferably comprises the step of depositing substantially sufficient charge for a desired steady state switched on state of the device on the gate while the capacitance has said initial value.

The invention also extends to a drive circuit for a device as herein defined and/or described.

BRIEF DESCRIPTION OF THE ACCOMPANYING DIAGRAMS

The invention will now further be described, by way of example only, with reference to the accompanying diagrams wherein:

figure 1 is a schematic representation of a known insulated gate semiconductor device in the form of a power MOSFET;

figure 2(a) is a diagrammatic representation of a gate structure of the MOSFET while it is off;

figure 2(b) is a diagrammatic representation of a gate structure of the MOSFET when it is partially on;

figure 2(c) is a diagrammatic representation of a gate structure of the MOSFET when it is fully switched on;

figure 3 is a schematic representation of a first embodiment of a power MOSFET according to the invention;

figure 4 is a typical graph for the steady state of gate-to-source voltage against total gate charge marked A of a conventional MOSFET as well as various similar graphs marked B for MOSFET's according to the invention;

figure 5 is a graph of total switching time against a ratio of initial charge transferred to the gate and the Miller charge of a variety of MOSFET's;

figure6 is a graph of drain-source rise time against turn-on delay time of a variety of MOSFET's;

figure 7 is a graph of minimum and maximum gate source voltages required on a MOSFET according to the invention against total switching time;

figure 8(a) are oscillographs of V_{GS} and V_{DS} against time for a MOSFET with a ratio $C_{fiss}/C_{iiss} \approx 2.16$;

figure 8(b) are similar graphs for a MOSFET with a ratio $C_{fiss}/C_{iiss} \approx 1.63$;

figure 8(c) are similar graphs for a MOSFET with a ratio $C_{fiss}/C_{iiss} \approx 1.34$;

figure 8(d) are similar graphs for a MOSFET with the ratio $C_{fiss}/C_{iiss} \approx 1.17$;

figure 9 is a schematic representation of a second embodiment of the MOSFET according to the invention;

figure 10 is a schematic representation of a third embodiment of the MOSFET according to the invention;

figure 11 is a block diagram of another embodiment of the device according to the invention; and

figure 12 is a basic diagram of drive circuit for a device according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A known insulated gate device in the form of a known power metal oxide silicon field effect transistor (MOSFET) is generally designated by the reference numeral 10 in figure 1.

The MOSFET 10 comprises a gate 12, a drain 14 and a source 16. The device 10 has a gate capacitance C_G between the gate and the source.

It is well known that when a voltage V_{GS} is applied to the gate as shown at 80 in figure 8(a), charge is deposited on the gate causing the device to switch on and a voltage V_{DS} to switch from a maximum value shown at 82 to a minimum value shown at 84. Similarly, when the charge is removed from the gate, the device is switched off and the voltage V_{DS} switches to the maximum value.

The total switching time T_s (illustrated in figure 8(a)) is constituted by the sum of a turn-on delay time T_{don} and a rise time T_r. The turn-on delay time is defined to be the time between rise of the gate-to-source voltage V_{GS} above 10% of its maximum value and the onset of drain-to-source conduction, that is when the voltage V_{DS} has decreased by 10%. The rise time is defined as the time interval corresponding to a decrease in V_{DS} from 90% to 10% of its maximum value when the device is switched on.

Referring to figures 2(a) to 2(c), in the known devices, the gate capacitance C_G may be modelled as effectively comprising two capacitors C_g and C_c in series. As shown in figures 2(a) to 2(c) the first

capacitor C_g is an invariable capacitor and its value scales to 1/d, being the effective thickness (d) of an insulation layer 18 at the gate of the device. The second capacitor C_c is a variable capacitor having a value of ∞ when the device is switched on as shown in figure 2(c), a value of $A/\propto_{max}$ when the device is off as shown in figure 2(a) and a value of $A/\propto$ (with $0 < \propto < \propto_{max}$) while the capacitance changes, i.e. the channel switches off or on. The gate capacitance C_G may hence be written as:

$$C_G = 1/[1/C_g(d) + 1/C_c(\propto)]$$

$$= A/(d + \propto)$$

where A is an effective area, which includes proper normalization constants. Thus, $\propto$ is a maximum ($\propto_{max}$) when the device is switched off as shown in figure 2(a) and $\propto = 0$ when the device is switched on as shown in figure 2(c).

Hence, the device has a gate or input capacitance with a first value C_{iiss} when the device is off and a second value C_{fiss} when the device is on. The capacitance retains the first value until the Miller effect takes effect.

An effective maximum conduction channel dielectricum thickness $(\beta) = \propto_{max}$ is defined, which is proportional to a difference in the inverse of the gate capacitance when the device is off C_{iiss} and when the device is on C_{fiss}, that is:

$$\beta \equiv A(1/C_{fiss} - 1/C_{fiss}) = \propto_{max}.$$

The ratio C_{fiss} / C_{iiss} may be written as $\frac{d + \propto_{max}}{d}$.

As shown in figure 3, according to the invention by increasing the effective thickness d_{ins} of the insulation layer 32 at the gate 34 and hence by decreasing the gate capacitance C_G, the total switching time T_s of a MOSFET 30 may be decreased. A minimum value for the effective thickness d_{ins} is given by:

$$d_{ins} \geq \beta / [\ (Q_{G(max)} / Q_{G(min)}) - 1\ ]$$

wherein $Q_{G(min)}$ is the minimum charge required for complete switching and wherein $Q_{G(max)}$ is the maximum allowable gate charge on the device which includes a safety margin. Destruction will occur when $Q \geqq Q_{G(max)}$.

Defining $V_{GS(min)}$ as the minimum gate voltage for complete switching and $V_{GS(max)}$ as the maximum allowable gate voltage on the device, before damage to the device, it is known that $Q_{G(max)} / Q_{G(min)} > V_{GS(max)} / V_{GS(min)}$. This inequality implies a slightly larger limit than that calculated from the charge ratios $Q_{G(max)} / Q_{G(min)}$:

$$d_{ins} \geq \beta / [\ (V_{GS(max)} / V_{GS(min)}) - 1\ ]$$

With this minimum effective thickness for d_{ins}, the switching time of the device is mainly limited by the gate source inductance and capacitance. By increasing d_{ins} beyond this minimum, allows for reducing the rise or fall time by compensating for the source inductance L_s voltage ε_s during switching and which is:

$$\varepsilon_s = L_s\, di/dt + iR_s$$

$$\varepsilon_{s\,(max)} \approx L_s\, I_{DS(max)} / T_s + I_{DS(max)}\, R_s.$$

In Table 1 there are provided relevant details of four differently modified MOSFET's with progressively decreasing gate capacitance, C_G.

Table 1

No.	Modified Input Gate Capacitance C_{iiss}, C_{fiss} (nF)	$\frac{C_{fiss}}{C_{iiss}}$	Applied Gate Voltage V_{GS} (volt)	Initial & Final Gate Charge Transferred $C_{iiss}V_{GS}$ & $C_{fiss}V_{GS}$ (nC)	Turn-on Delay Time Predicted & Observed $T_{d(on)}$ (ns)	**Measured Switching Time** T_S **(ns)**
i	1.2 2.6	2.16	15	18 40	6.3 6 (20 ns/div)	**38**
ii	0.86 1.4	1.63	32	28 45	5.3 5 (20 ns/div)	**20**
iii	0.58 0.78	1.34	120	70 94	4.4 <2 (10 ns/div)	**<4**
iv	0.35 0.41	1.17	200	70 82	3.4 < 2 (10 ns/div).	**<4**

For a conventional IRF 740 MOSFET:

$$\varepsilon_{s(max)} \approx 7.4 \text{ nH } (40 \text{ A}/27 \text{ ns}) + 4 \text{ volt} = 15 \text{ volt}$$

$$V_{G(internal)} \approx V_{GS(max)} - \varepsilon_{s(max)} = 20 \text{ volt} - 15 \text{ volt} = 5 \text{ volt}$$

For the device in row iv of Table 1

$$\varepsilon_{s(max)} \approx 7.4 \text{ nH } (40 \text{ A}/2.5 \text{ ns}) + 5 \text{ volt} = 123 \text{ volt}$$

$$V_{G(internal)} \approx V_{GS(max)} - \varepsilon_{s(max)} \approx 200 \text{ volt} - 123 \text{ volt} = 77 \text{ volt}$$

From this example it is clear that $V_{G(internal)}$ is still larger than the modified threshold gate voltage $V_{GSTM} = V_{GS(min)} = 73$ volt, shown in figure 4, and the slow rise time due to the Miller effect is thus effectively counteracted. It follows that minimization of the product $L_S C_{iiss}$ minimizes the switching time T_s of the device, assuming the combined gate and source serves resistance is negligible.

If a gate voltage, V_{GS}, substantially larger than the threshold gate voltage, V_{GST}, is supplied in a time much shorter than the turn-on delay time, the latter may be approximated as:

$$T_{don} \approx (2/3)(L_S C_{iiss})^{1/2}.$$

It can be shown that:

$$T_s \propto 1/d_{ins}^{1/2}$$

which indicates that the total switching time is reduced by increasing the effective thickness d_{ins} of layer 32.

Another important feature of the invention is that at least a minimum required charge $Q_{G(min)}$ or Miller charge (see figure 4) must be transferred to the gate while the gate capacitance assumes its lower initial value of C_{iiss} rather when the larger input capacitance C_{fiss} determines the final switched state of the MOSFET. Hence the charge to be transferred is

$$Q_G = V_{GS}C_{iiss} \geq Q_{G(min)}.$$

Thus, the following minimum source to gate voltage must be applied.

$$V_{GS} \geq V_{GS}(min) = Q_{G(min)}/C_{iiss.}$$

Also,

$$Q_G = V_{GS}C_{fiss} \leq Q_{G(max)}$$

and the corresponding voltage limit is given by

$$V_{GS} \leq V_{GS(max)} = Q_{G(max)} / C_{fiss.}$$

This could also be written as:

$$C_{fiss} / C_{iiss} \leq Q_{G(max)} / Q_{G(min)}$$

or

$$C_{fiss} / C_{iiss} \leq V_{GS(max)} / V_{GS(min).}$$

Oscillograms illustrating V_{GS} and V_{DS} against time during switching on for each of the devices referenced i to iv in Table 1 are shown in figures 8(a) to 8(d) respectively. The decrease in gate capacitance is clear from the second column in the Table, and the larger required input V_{GS} and decreasing switching times are clear from both the Table and the oscillograms.

The last two devices iii and iv in Table 1 with minimized gate capacitance and wherein the ratio $C_{fiss}/ C_{iiss} \leq 1,34$, represent MOSFET's close to optimum, since the initial gate charge is already more than the minimum gate charge $Q_{G(min)}$ (shown in figure 4 and which for a typical MOSFET is in the order of 30nC) required for complete switching. The increased gate to source input voltage V_{GS} and spectacular drop in total switching times T_s are noticeable.

In figure 4, comparative graphs for a known MOSFET is shown at A and for MOSFET's according to the invention at B. The ratio C_{fiss}/C_{iiss} for the known IRF 740 MOSFET is in the order of 2.5 whereas the same ratio for the last device according to the invention in Table 1 is 1.17. The device according to the invention has a total switching time of < 4ns which is about an order faster than the 38ns of the known and comparable IRF 740 MOSFET.

In figure 5 there is shown a graph of total switching time as a function of the initial gate charge relative to the minimum gate charge $Q_{G(min)}$. The circle at 40 represents standard operation of an IRF 740 MOSFET. However, the circles at 42 and 44 illustrate the improved operation of the MOSFET's referenced iii and iv in Table 1.

In figure 6 there is shown a graph of rise time T_r against turn-on delay time T_{don} for a plurality of different devices. The mark at 50 indicates standard operation of an IRF 740 MOSFET and the circles 52 and 54 indicate the improvement in total switching time T_S of the devices referenced iii and iv in Table 1 to a point where the rise time becomes negligible and the total switching time T_S approximates the turn-on delay time T_{don}.

It can further be shown that the product of V_{GS} and the square of the total switching time T_S is band limited as follows:

$$(2\pi/3)^2 Q_{G(min)} L_S \leq V_{ES} T_S \leq (2\pi/3)^2 Q_{G(max)} L_S$$

which means that the operating voltage V_{GS} of the device according to the invention (which is much higher than the corresponding voltage for prior art devices) is limited as follows:

$$(2\pi/3)^2 Q_{G(min)} L_S / T_S^2 \leq V_{GS} \leq (2\pi/3)^2 Q_{G(max)} L_S / T_S^2$$

and as illustrated in figure 7. The internal source resistance R_S has a negligible effect on these expressions and is therefore omitted for better clarity.

Hence, by minimizing the product of Miller charge or $Q_{G(min)}$ and L_S, reduced total switching times T_S and required operating voltages V_{GS} may be achieved.

In figure 9 there is shown a further embodiment of the device according to the invention and designated 90. The device comprises a gate 92, connected to a gate terminal 94. The insulation layer with increased effective thickness d_{ins} is shown at 96. Conventional source and drain terminals are shown at 98 and 99 respectively. A further and so-called floating gate 95 is connected to a fourth and user accessible terminal 97.

In figure 10, yet another embodiment of the device according to the invention is shown at 100. In this case, the further gate 95 is not connected to a user accessible terminal, similar to terminal 97, but biasing resistors 102 and 104 may be provided as discrete components or integral with the chip body 106.

In figure 11, still a further embodiment of the device is shown at 110. The device 110 comprises a conventional MOSFET 112 having a gate 114. A capacitor 116 is connected in series between the gate and a gate terminal 118 of the device. The drain and source of the MOSFET are connected to a drain terminal 120 and source terminal 122 respectively. The device is packaged in a single package 124 providing the aforementioned terminals. An optional fourth terminal 124 connected to the gate 114 may also be provided. The capacitor 116 may be integrated with the MOSFET on a single chip. In other embodiments, the capacitor may be a discrete capacitor, but packaged in the same package 124. In still other embodiments, the optional fourth terminal may be omitted and biasing resistors between the gate terminal and the gate and between the gate and the source may be provided in the same package.

In figure 12 there is shown a diagram of a drive circuit 130 for the device 30, 90, 100 and 110 according to the invention. The drive circuit comprises a voltage source 132 (typically 50V – 600V and which may even exceed V_{DD}) and a fast switching device 134 connected in a circuit and in close proximity to the gate terminal of the device according to the invention to reduce unwanted inductance in the gate source circuit.

In use, the fast switching device 134 is controlled to apply a voltage which is sufficiently larger than the threshold voltage of the device to the gate of the device. As is clear from table 1, this voltage is larger than the voltage required in conventional devices. Due to the reduced LCR parameters in the gate source circuit, charge transfer to the gate of the device will be faster than with conventional devices which results in the faster switching times in the drain source circuit as shown in table 1.

CLAIMS

1. An insulated gate device comprising a gate connected to a gate terminal and having a variable input capacitance at the gate terminal as the device is switched between an off state and an on state, a ratio between a final value of the capacitance when the device is on and an initial value of the capacitance when the device is off is smaller than 2.0.

2. A device as claimed in claim 1 comprising a power metal oxide silicon field effect transistor (MOSFET).

3. A device as claimed in claim I or claim 2 wherein the ratio is less than 1.5.

4. A device as claimed in claim 3 wherein the ratio is substantially equal to 1.

5. A device as claimed in any one of claims 1 to 4 comprising a capacitor connected between the gate terminal and the gate of the device.

6. A device as claimed in any one of claims 2 to 5 wherein the MOSFET has a vertical structure in that the gate and a source of the device are provided on one face of a chip body of the device and a drain of the MOSFET is provided on an opposite face of the body.

7. A device as claimed in claim 6 wherein the capacitor is integrated on the chip body.

8. A device as claimed in claim 7 wherein the capacitor is superimposed on the gate of the MOSFET.

9. A device as claimed in claimed in claim 5 wherein the capacitor is a discrete component connected in series between the gate and the gate terminal and packaged in the same package.

10. A device as claimed in any one of claims 5 to 9 wherein the gate is connected directly to a fourth terminal of the device.

11. A device as claimed in claim 9 wherein biasing resistors connected to the gate are included in the same package.

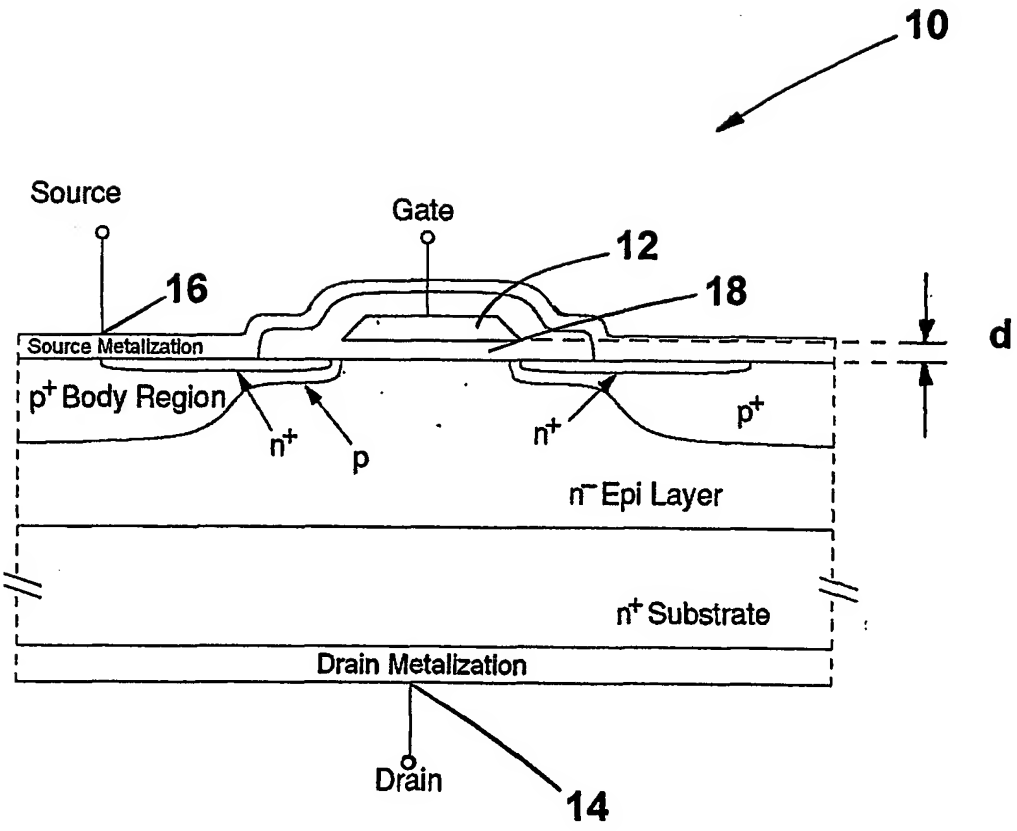
10
Source
Gate
12
16
18
d
Source Metalization
p+ Body Region
n+
p
n+
p+
n- Epi Layer
n+ Substrate
Drain Metalization
Drain
14

FIGURE 1

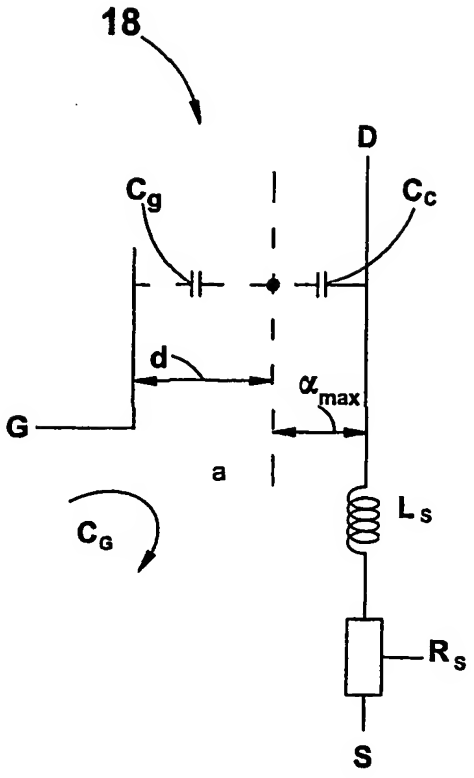

FIGURE 2(a)

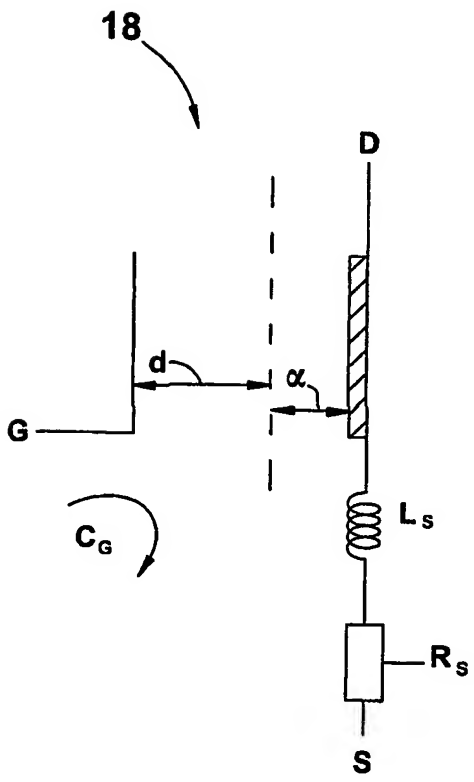

FIGURE 2(b)

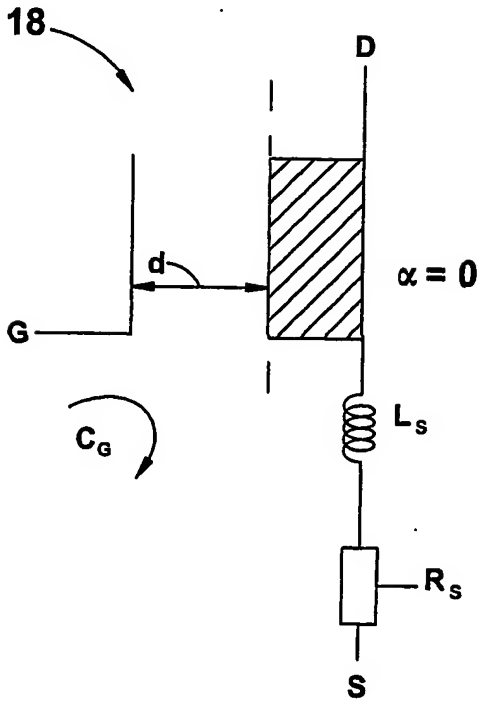

FIGURE 2(c)

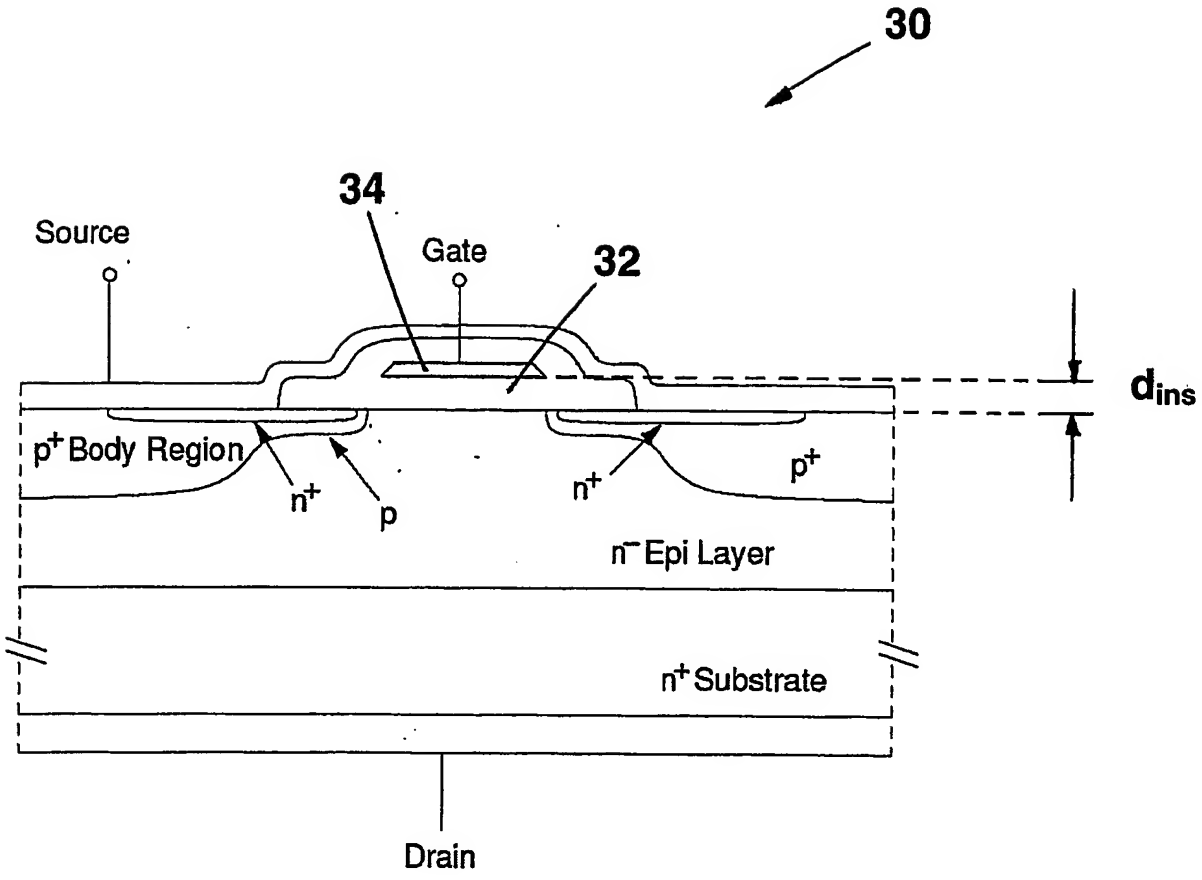
30
34
Source
Gate
32
d_{ins}
p^+ Body Region
n^+
p
n^+
p^+
n^- Epi Layer
n^+ Substrate
Drain

FIGURE 3

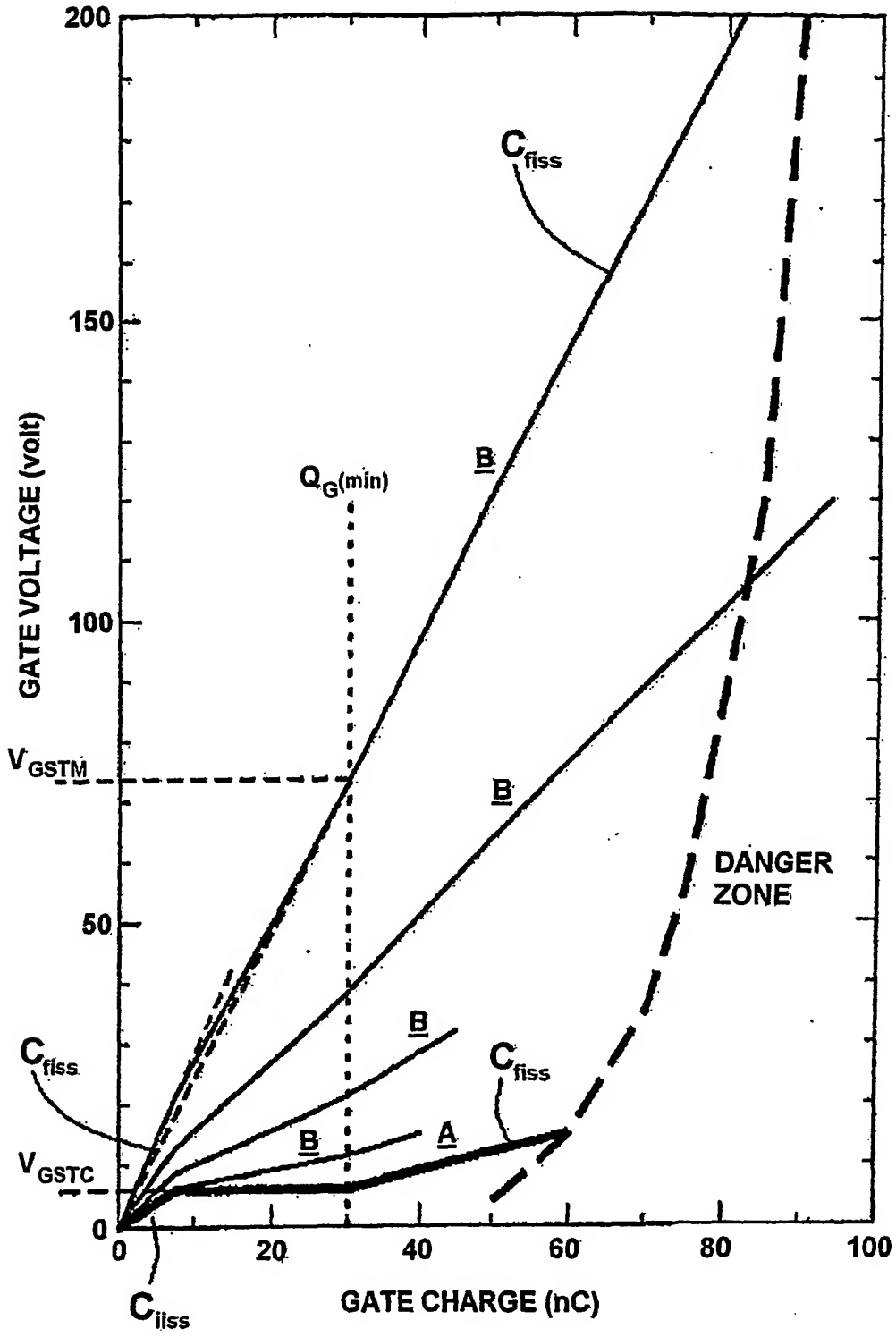
200
150
100
50
0
GATE VOLTAGE (volt)
C_{fiss}
$Q_{G(min)}$
B
B
B
B
A
V_{GSTM}
V_{GSTC}
C_{fiss}
C_{fiss}
C_{fiss}
DANGER ZONE
0
20
40
60
80
100
GATE CHARGE (nC)

FIGURE 4

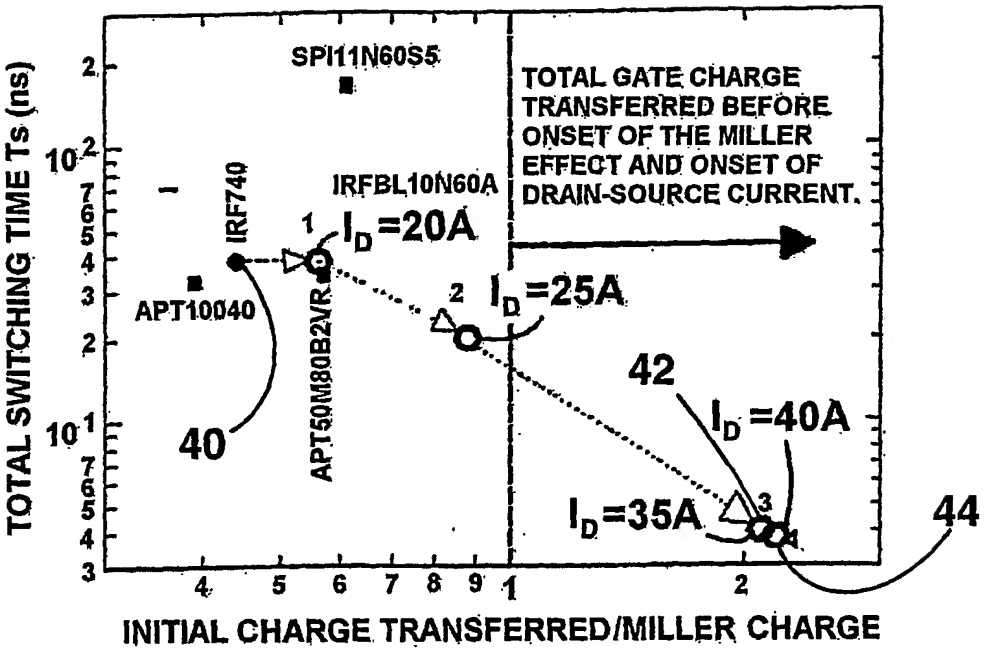
TOTAL SWITCHING TIME Ts (ns)
INITIAL CHARGE TRANSFERRED/MILLER CHARGE
SPI11N60S5
IRF740
IRFBL10N60A
APT10040
APT50M80B2VR
TOTAL GATE CHARGE TRANSFERRED BEFORE ONSET OF THE MILLER EFFECT AND ONSET OF DRAIN-SOURCE CURRENT.
I_D=20A
I_D=25A
I_D=40A
I_D=35A
40
42
44
1
2
3
4

FIGURE 5

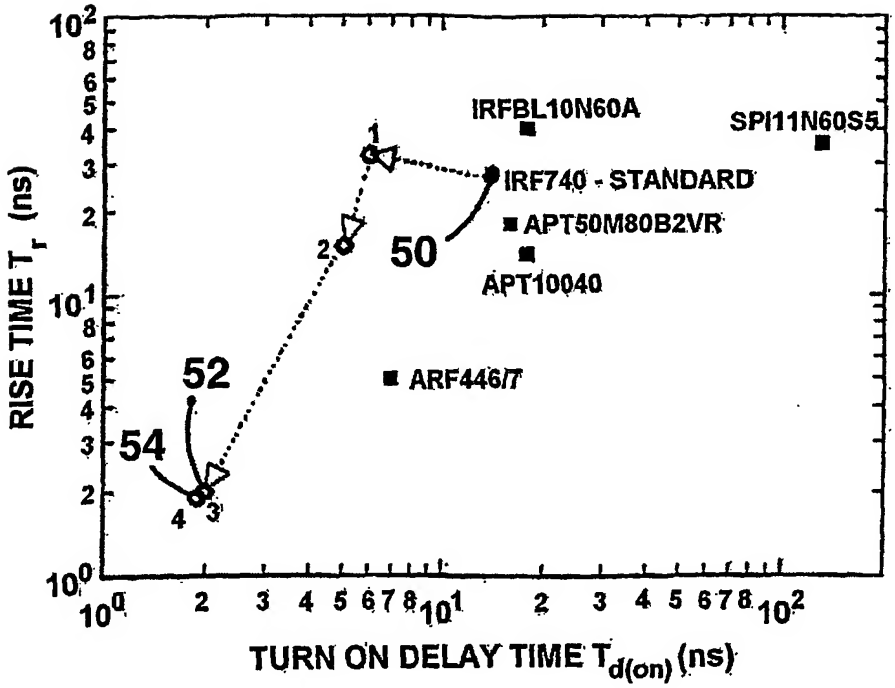
RISE TIME T_r (ns)
TURN ON DELAY TIME $T_{d(on)}$ (ns)
IRFBL10N60A
SPI11N60S5
IRF740 - STANDARD
APT50M80B2VR
APT10040
ARF446/7
50
52
54
1
2
3
4

FIGURE 6

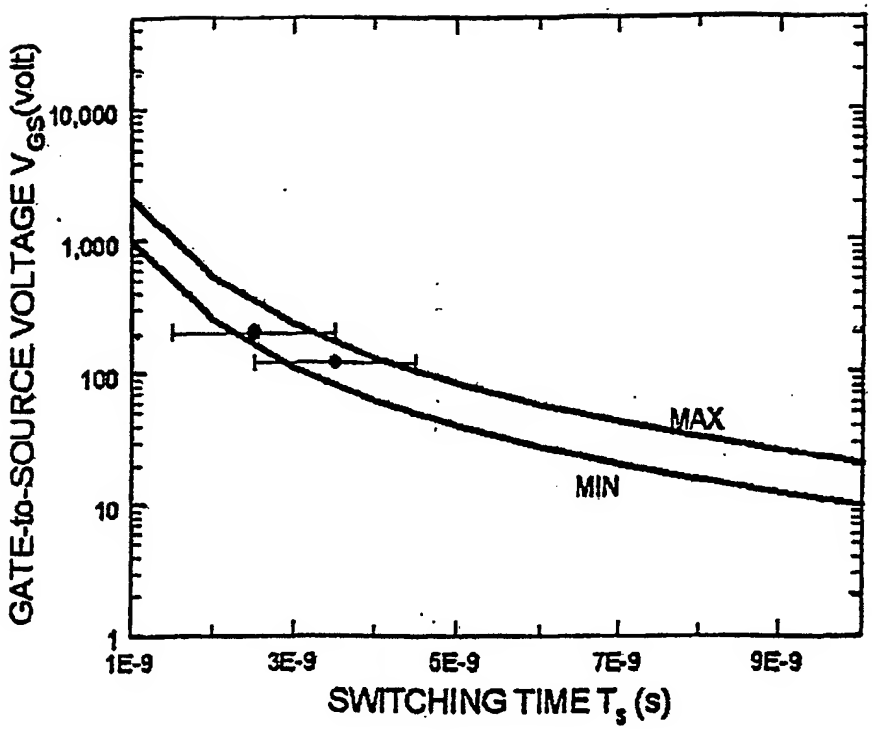
GATE-to-SOURCE VOLTAGE V_{GS}(volt)
10,000
1,000
100
10
1
1E-9
3E-9
5E-9
7E-9
9E-9
SWITCHING TIME T_s (s)
MAX
MIN

FIGURE 7

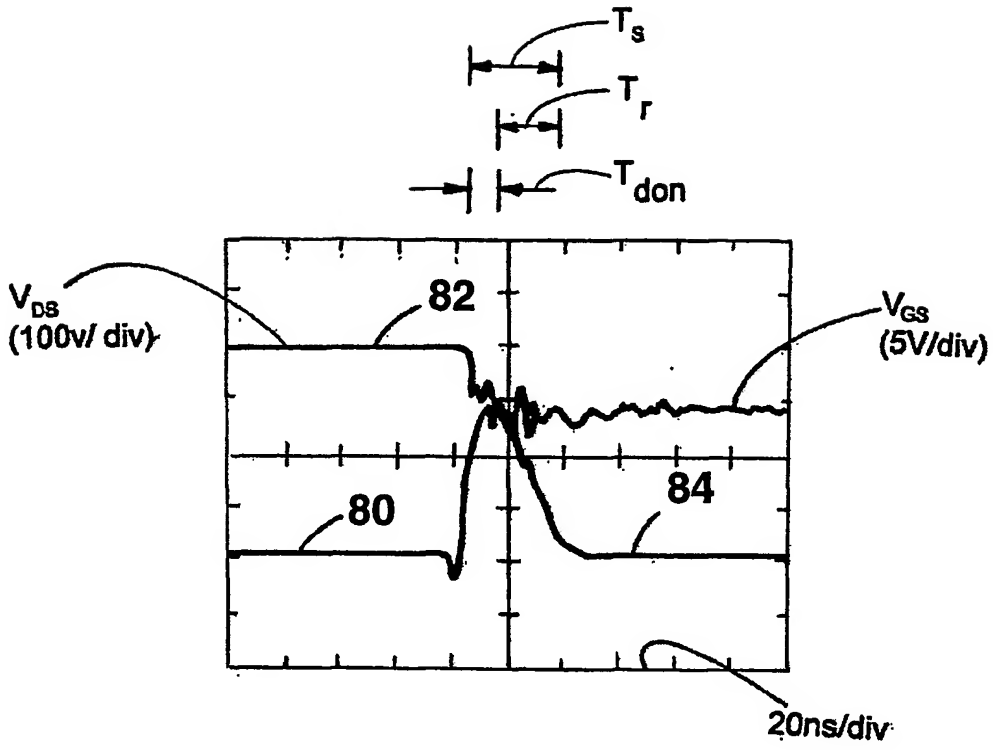

FIGURE 8(a)

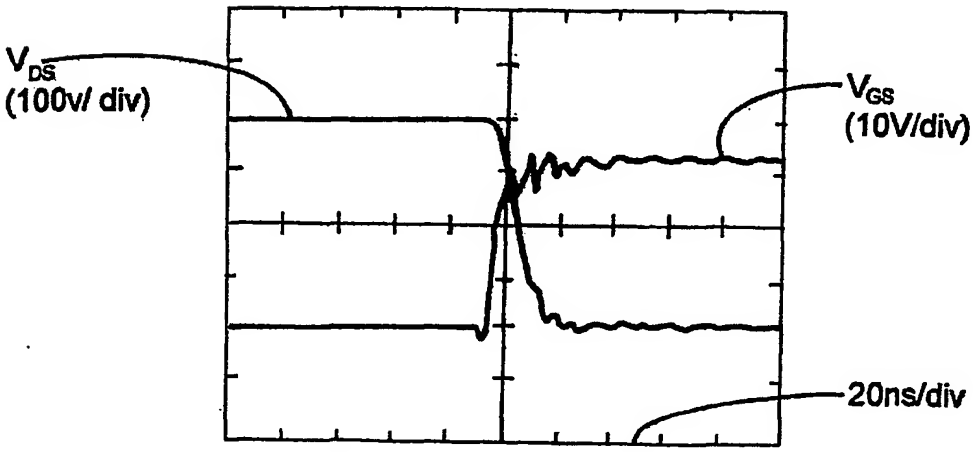

FIGURE 8(b)

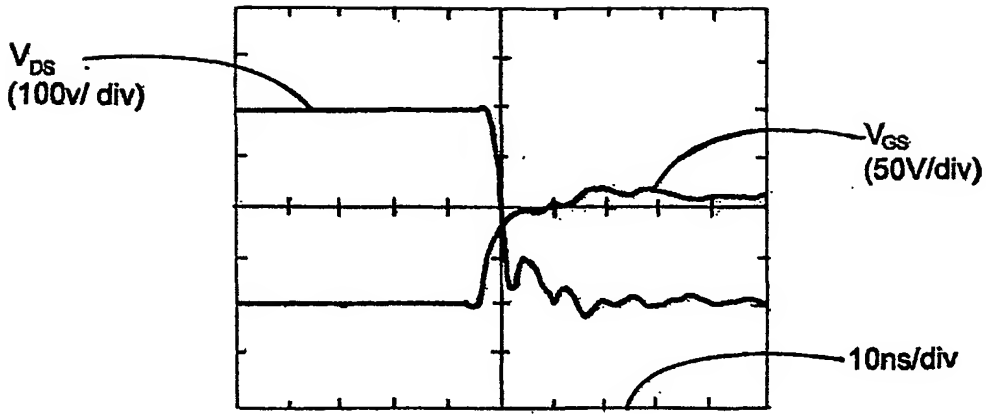

FIGURE 8(c)

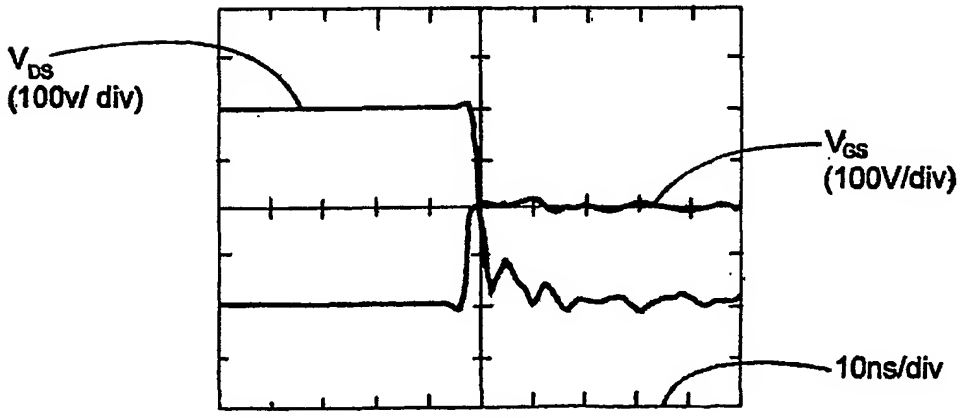

FIGURE 8(d)

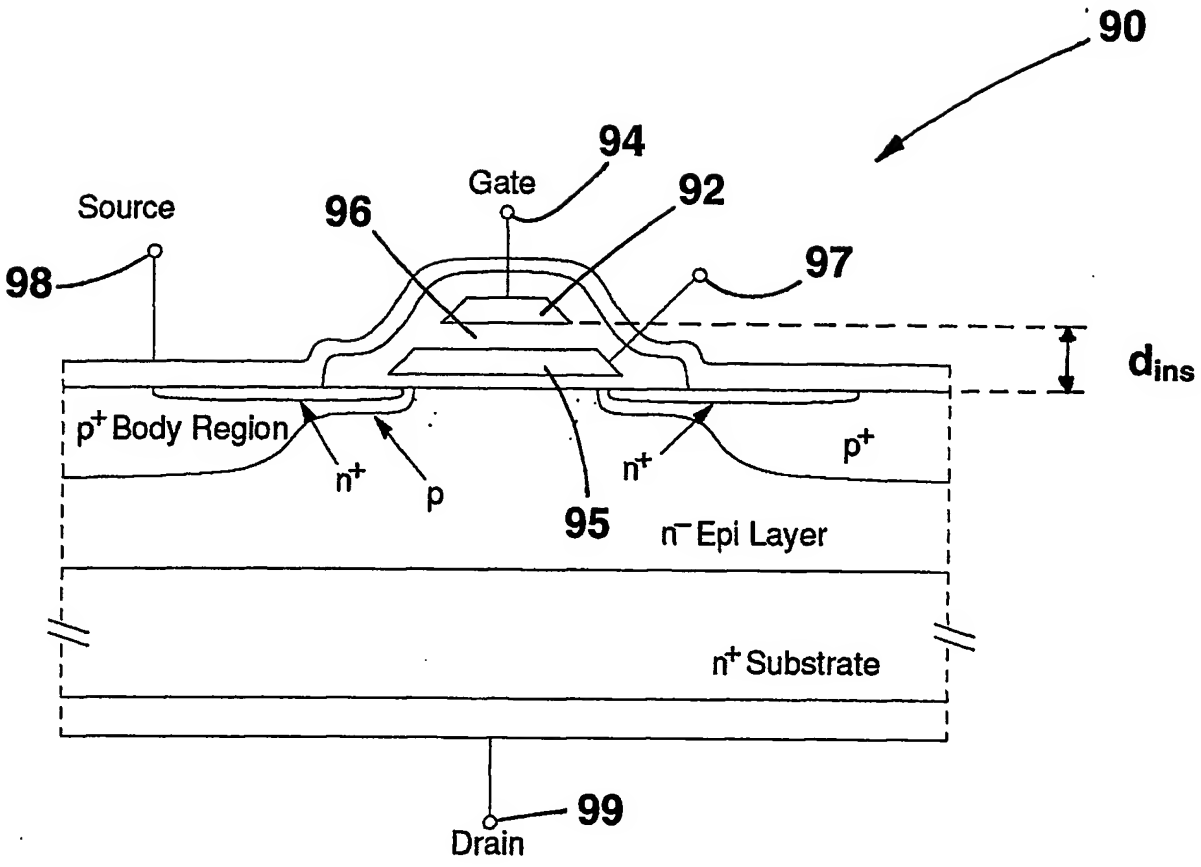
90
94
Gate
92
Source
96
97
98
d_{ins}
p^+ Body Region
n^+
p
95
n^- Epi Layer
n^+
p^+
n^+ Substrate
99
Drain

FIGURE 9

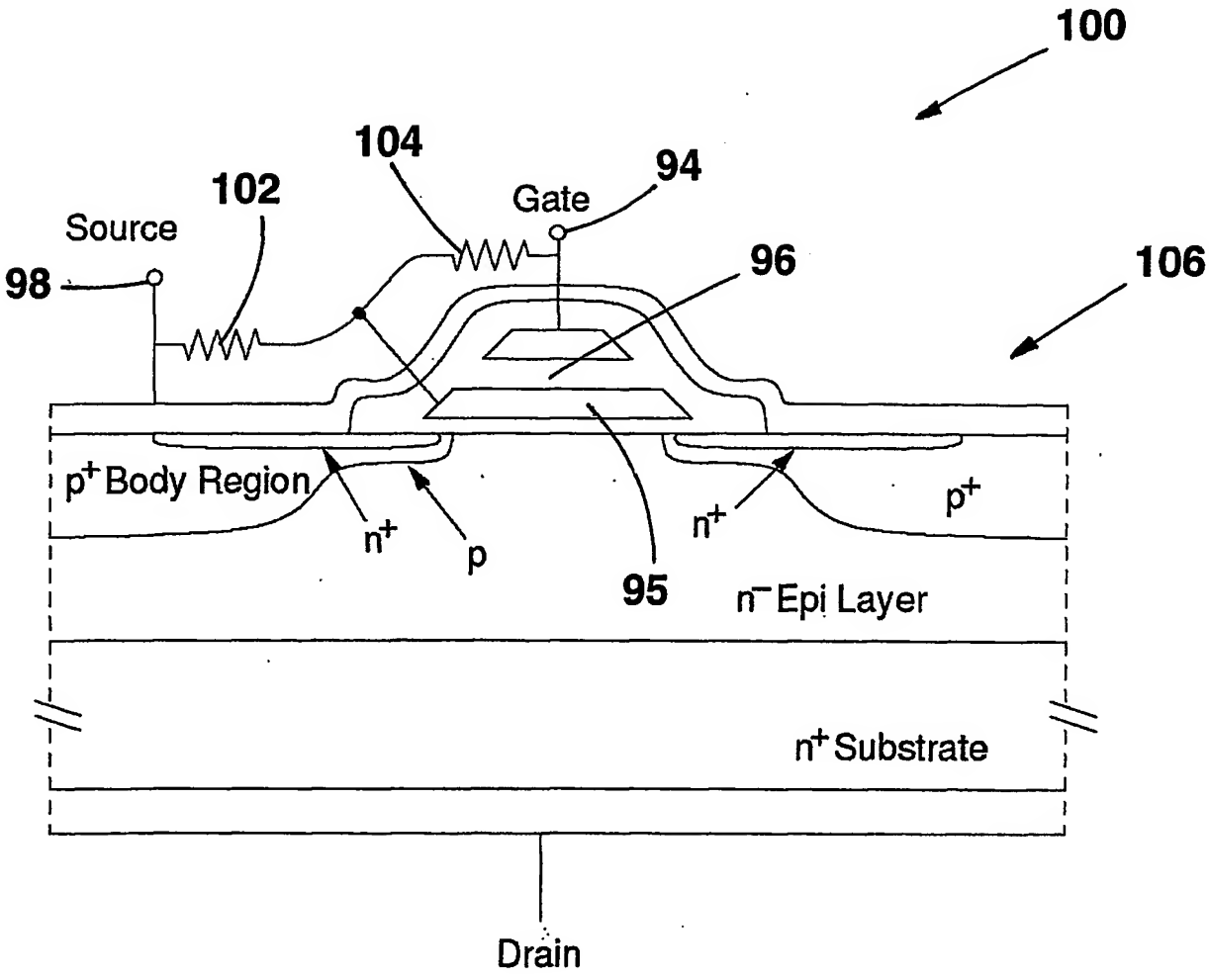
100
104
94
102
Gate
Source
98
96
106
p+ Body Region
n+
p
95
n+
p+
n- Epi Layer
n+ Substrate
Drain

FIGURE 10

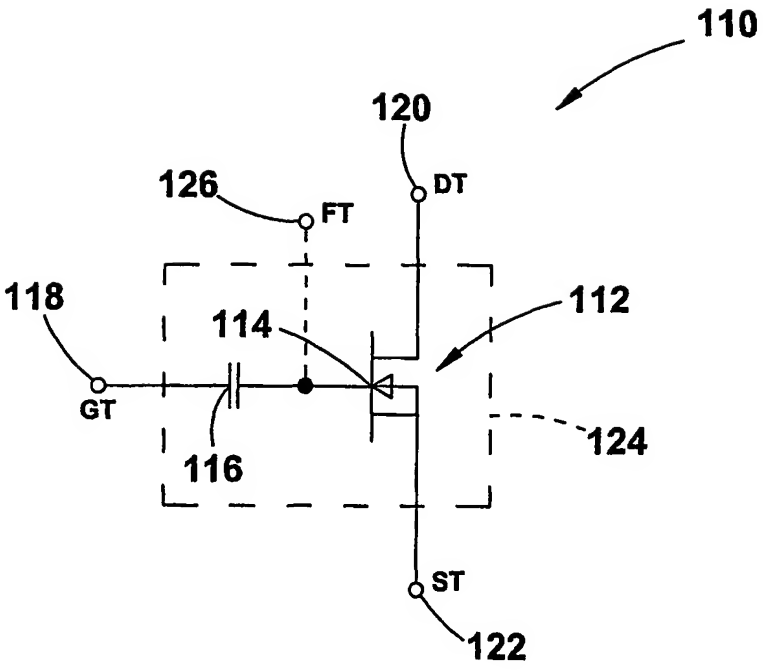

FIGURE 11

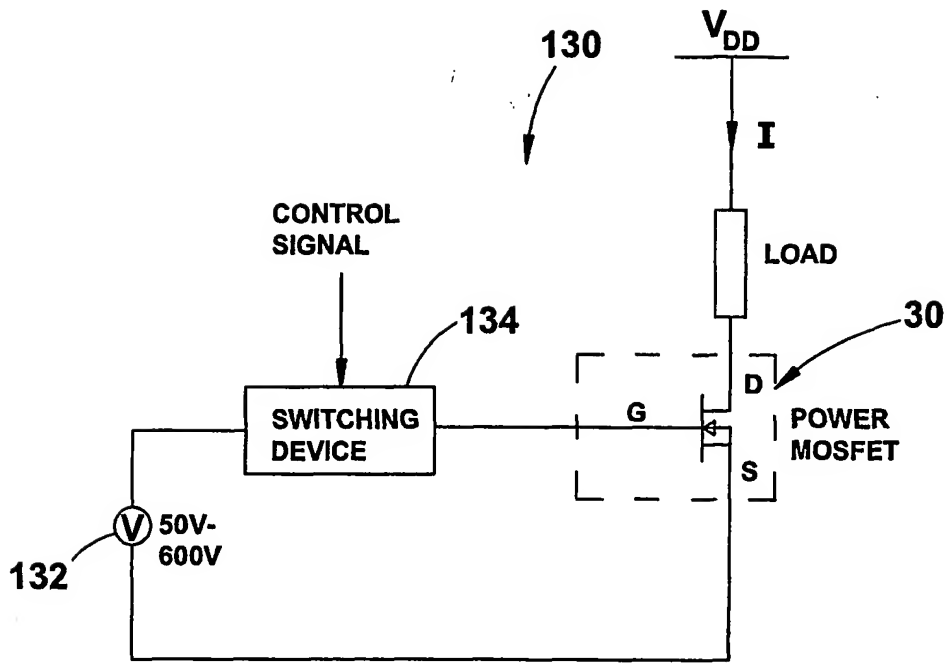
130
V_{DD}
I
CONTROL SIGNAL
LOAD
134
30
D
G
SWITCHING DEVICE
POWER MOSFET
S
V
50V-600V
132

FIGURE 12

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L29/78 H01[redacted]/423 H03K17/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L H03K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/13257 A (TIHANYL JENOE ; HIRLER FRANZ (DE); WERNER WOLFGANG (DE); INFINEON TECH) 14 February 2002 (2002-02-14) page 4, line 5 - line 12 page 15, line 1 - line 28; figure 5	1-8,10
X	EP 1 096 573 A (INTERSIL CORP) 2 May 2001 (2001-05-02) the whole document	1-4,6
X	WO 91/11826 A (QUIGG FRED L) 8 August 1991 (1991-08-08) abstract	1-4,6
X	DE 199 05 421 A (SEMIKRON ELEKTRONIK GMBH) 24 August 2000 (2000-08-24) abstract; figures 3a-5 page 15, line 1 - line 28; figure 5	1-4,6

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 July 2004	22/07/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lantier, R

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with Indicat[redacted]ere appropriate, of the relevant passages	Relevant to claim No.
X	VISHAY DATASHEET OF N-CHANNEL 240-V MOSFETS TN2410L, VN2406DL, VN2410LLS, 'Online! 16 July 2001 (2001-07-16), XP002287713 Retrieved from the Internet: URL:www.vishay.com> 'retrieved on 2004-07-08! pages 11-4; figure third	1-4
X,P	US 6 589 830 B1 (ZENG JUN) 8 July 2003 (2003-07-08) column 4, line 3 - line 57; figures 13-16	1-4,6
A	US 5 392 187 A (BALIGA BANTVAL J) 21 February 1995 (1995-02-21) abstract; figures 3,5	5,6,9,11
A	US 4 796 174 A (NADD BRUNO) 3 January 1989 (1989-01-03) abstract	5,6,9,11

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